

Underground Tank Technology Update

Vol. 11, No. 2
March/April 1997

Department of Engineering Professional Development The College of Engineering University of Wisconsin-Madison

Underground Tank Technology Update is published bimonthly by the University of Wisconsin-Madison, Department of Engineering Professional Development. *UTTU* supplies useful information to federal, state, and local officials working with groundwater technology and to other interested technical specialists. For new subscriptions or address corrections, use the form on inside back page.

UTTU is funded by the U.S. EPA under Cooperative Agreement No. L005924-01 to the University of Wisconsin-Madison, which is responsible for its preparation. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Comments and suggestions are welcome and may be directed to John T. Quigley, Project Director, 432 N. Lake St., Madison, WI 53706. Tel 608/265-2083.

If you have a problem locating a reference cited in *UTTU*, please contact Pat Dutt Komor by e-mail at pdkomor@msn.com, or call her at 607/257-6801.

Advisory Board

Gilberto Alvarez, Environmental Engineer
Office of Underground Storage Tanks
U.S. EPA, Region 5, Chicago, Illinois

Mark D. Millsop, Hydrogeologist
GME Consultants
Crosby, Minnesota

George Mickelson, Environmental Engineer
Wisconsin Department of Natural Resources
Madison, Wisconsin

Paul Miller, Engineer
Office of Underground Storage Tanks
U.S. EPA, Washington D.C.

Phil O'Leary, Associate Professor
Department of Engineering Professional Development, UW-Madison

Gerald W. Phillips
U.S. EPA, Region 5, Chicago, Illinois

Charlita Rosal, Environmental Scientist
U.S. EPA, CRD-LV, Las Vegas, Nevada

Staff

John T. Quigley

Pat Dutt Komor

Darrell Petska

Debbie Benell

Susan Kummer/Artifax

Project Director

Technical Writer

Copy Editor

Program Assistant

Graphics

SPECIAL ISSUE

on Accelerated Site Characterization

In this issue

- ASTM's accelerated site characterization 2
A summary of ASTM's standard on accelerated site characterization
- Field analytical methods 6
Seven field analytical methods for identifying petroleum hydrocarbons
- Direct push technologies 10
Types of direct push technologies used by field workers to characterize sites. Includes a short list of *UTTU* references pertaining to on-site characterization
- The Fury robotic system 13
A robotic system that inspects tank integrity without tank cutting or emptying the tank
- The view from U.S. EPA 14
U.S. EPA's policy on accelerated site assessment
- Information sources 15
Information on recent publications, Web sites, courses and seminars



ASTM's accelerated site characterization

ASTM's PS3-95, "Provisional Standard Guide for Accelerated Site Characterization for Confirmed or Suspected Petroleum Releases" (1996), from which this article is summarized (often verbatim), describes a process for collecting site characterization information in one mobilization. Accelerated site characterization relies on:

- rapid sampling techniques
- on-site analytical methods
- on-site interpretation and iteration of field data to refine the conceptual model for understanding site conditions as the characterization proceeds

This information can be used to determine the need for

- interim remedial actions (IRA)
- site classification or prioritization, or both
- future corrective actions and remediation

Although written with petroleum products in mind, this provision may be applied to a variety of chemicals of concern. (*Editor's note: we've used this process on many hydrocarbon sites, as well as VOC/solvent and wood preservative sites.*) Terminology used in this guidance includes the following:

Accelerated site characterization (ASC): a one-mobilization process for collecting and evaluating information pertaining to site geology/hydrogeology, nature, and distribution of the chemicals of concern, potential exposure pathways, and receptors. A conventional site characterization can provide high-quality data; however, multiple mobilizations often prolong the process required to adequately characterize subsurface conditions. The ASC employs rapid sampling techniques, on-site chemical analysis and geological/hydrogeological evaluation, and field decision making to provide a "snap-shot" of subsurface conditions.

Active remediation: actions taken to reduce the concentration of chemicals of concern. Active remediation could be implemented when the no-further-action and passive remediation courses of action are not appropriate.

Chemicals of concern (COC): specific constituents that are identified for evaluation in the site characterization process.

Conceptual model: a summary of information about a site. Available site information is compiled into simple graphics to develop an understanding of site conditions.

Corrective action: activities performed in response to a suspected or confirmed release. Activities include one or more of the following: site characterization, monitoring of natural attenuation, interim remedial action, remedial action, operation and maintenance of equipment, monitoring of progress and termination of remedial action.

Exposure pathways: the course a COC takes from the source area to an exposed organism. An exposure pathway describes a unique mechanism by which an individual or population is exposed to a COC originating from a site. Each exposure pathway includes a source or release from a source, a point of exposure, and an exposure route. If the exposure point differs from the source, the transport/exposure medium (e.g., air) or media are also included.

Facility: the property containing the source of the COC where a release has occurred.

Field-generated analytical data: information generated on-site immediately after sample acquisition; the data used to direct the site characterization process. Included are contaminant concentrations in air, soil, soil vapor and/or groundwater, and geologic/hydrogeologic conditions.

Indicator compounds: compounds in groundwater, soil, or air, specific to the petroleum product released; they are used to confirm the existence of the petroleum product, define the extent of the COC, define the target levels, monitor progress of the remedial action, and identify the termination point of the remedial action.

Mobilization: the movement of equipment and personnel to the site, conducted during a continuous time frame to prepare for, collect, and evaluate site characterization data. These activities, when conducted as one continuous event (from one day to several weeks, although the vast majority of ASC sites are 1 to 10-day projects), are referred to as a single mobilization. Activities that are not conducted continuously are referred to as multiple-site mobilizations.

On-site analytical methods: methods or techniques that measure physical properties or presence of COC or indicator compounds in soil, soil vapor, and groundwater immediately or within a relatively short period of time; the methods are used during a site characterization. Measurement capabilities range from a qualitative (positive/negative) response to below parts per billion (sub-ppb) quantitation. Accuracy and precision of data from the methods depend on the method detection limits and QA/QC procedures.

On-site manager: an individual who is on-site during field activities and responsible for directing field activities and making decisions during the site characterization. The on-site manager should be familiar with the purpose of the site characterization, pertinent existing data, and the data collection and analysis program. The on-site manager, who is the principal investigator, develops and refines the conceptual understanding/model of the site conditions. This individual should have the necessary experience and background to perform the required site characterization activities and to accurately interpret the results and direct the investigation. Sufficient qualification criteria include knowledge and experience in the following areas:

- soil and groundwater sampling and analytical methods to be used at the site
- fate and transport of petroleum hydrocarbons in the subsurface

- local geology/hydrogeology
- local regulations and ordinances
- personal health and safety requirements
- evaluation/interpretation of site characterization results

Petroleum: including crude oil or any fraction thereof that is liquid at standard conditions of temperature and pressure (60° F at 14.7 psia). The term includes petroleum-based substances comprised of a complex blend of hydrocarbons derived from crude oil through processes of separation, conversion, upgrading, and finishing, such as motor fuels, jet oils, lubricants, petroleum solvents and used oils.

Points of exposure: the point(s) at which an individual or population may come in contact with a COC originating from a site.

Quality assurance/quality control (QA/QC): the use of standards and procedures to ensure that samples collected and data generated are reliable, reproducible, and verifiable.

Rapid sampling tools: equipment and techniques that allow collection of samples from different media, in relatively short time periods, for on-site chemical analysis and geologic/hydrogeologic evaluation within the same mobilization.

Receptors: persons, structures, utilities, surface water, and water supply wells that are or may be adversely affected by a release.

Release: any spilling, leaking, emitting, discharging, escaping, leaching or disposing of petroleum products into groundwater, surface water, soils or air.

Site characterization: an evaluation of subsurface geology/hydrogeology, and surface characteristics to determine if a release has occurred, the level of the COC, and the extent of the migration of the COC. The data collected on soil, soil vapor and groundwater quality, and potential exposure pathways and receptors may be used to generate information to support remedial action decisions.

Source area: the location of liquid hydrocarbons in relation to the zones of highest soil or groundwater concentration, or both, of the COC; usually where the release occurred.

Significance and use of the provision

The primary goal of an ASC is to complete a site characterization in one mobilization. This can be accomplished by utilizing rapid sampling tools and techniques, field-generated analytical data, and on-site interpretation of results. Evaluation of data concurrent with the investigation allows the on-site manager to select subsequent sampling points based on actual subsurface conditions, resulting in a more comprehensive and cost-effective "snapshot" of subsurface conditions. The ASC process has the following advantages:

- immediate identification of potential risks to human or environmental receptors or potential liabilities or both
- rapid determination of the need for interim remedial actions, site classification and prioritization
- rapid sample collection and analysis, near-contemporaneous analytical results, and maximum data comparability
- optimization of sample point locations and analytical methods
- greater number of data points for resources expended
- near immediate data availability for accelerating corrective action decisions
- collection of vertical and horizontal data, allowing for three-dimensional delineation of COC in soil, soil vapor or groundwater

The ASC process requires the use of an on-site manager to guide the characterization. Without an individual on-site who is able to interpret data as it is generated, and who is authorized to adjust sample locations or investigation scope, or both, an ASC has little chance of meeting its objective of full characterization in one mobilization.

(Editor's note: disadvantages of the ASC process include the need for a drill rig to obtain contaminated samples from difficult geological environments; and the possibility that obtained data may poorly define aquifer parameters.)

The ASC process

The ASC process allows for the collection, analysis and evaluation of geologic/hydrogeologic and chemical data while investigators are on-site (see flowchart in Figure 1). The following activities are performed during an ASC:

- interpretation and evaluation of field-generated data as it is collected
- continuous refinement of the conceptual model, or the understanding of site conditions
- modification of the sampling and analysis program to address any necessary adjustments in the scope of work
- collection of additional data necessary to complete the characterization

For site characterization, the scope of work and priority will vary depending upon the purpose of the specific characterization. Purposes can include:

- hazard determination
- initial response action
- release confirmation
- risk determination
- corrective action evaluation
- regulatory compliance
- real estate transaction

The scope of the ASC is determined prior to mobilization but will often be revised based upon interpretation of the field-generated data. The regional and site-specific information should be obtained prior to mobilization. A review of existing site data and a site visit are important in the design of a data collection and analysis program and in the development of the conceptual model. Information obtained through the site visit, interviews, and records search include the following:

- local and regional geologic/hydrogeologic maps to identify general soil types/regional depth to bedrock, rock type, depth to groundwater and aquifer properties
- past and current land use of the site and adjacent properties (including future land use if known)

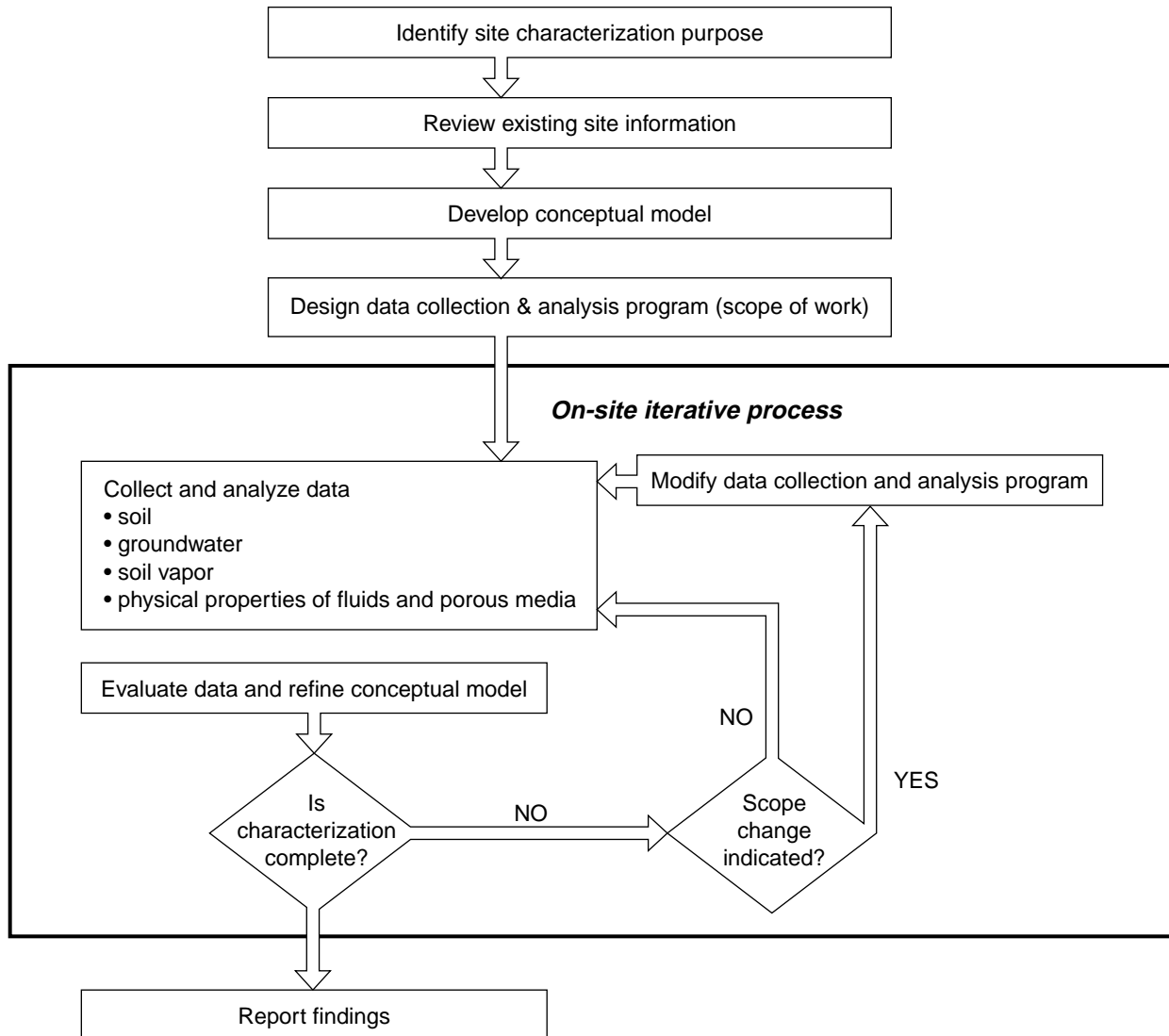


Figure 1. Accelerated site characterization process (from ASTM, 1996).

- location of potential release sources (for example, current and former storage tank systems)
- releases, spills and overfill incidents on-site and on adjacent properties
- previous or on-going corrective action activities or both, on-site and on nearby properties
- potential human health and environmental receptors, such as basements, private and public water supply wells, surface waters, and streams within a given proximity of the site
- potential transport to exposure pathways or specific points of exposure or both
- other potential off-site sources of COC
- site conditions that may affect the health and safety plan

The conceptual model

The conceptual model is the starting point of the investigation and is a basis for planning field activities. The conceptual model, developed from the compilation and interpretation of all existing information, may include the following:

- anticipated depths of subsurface geologic units
- anticipated groundwater depth and flow direction(s) and possible interaction with surface water bodies
- site layout, including areas and depths of artificial fill (tank and trench backfill), subsurface utility lines, and subsurface piping
- existing soil and groundwater analytical data and information regarding release location and volume
- potential releases in the site vicinity
- location of potential receptors

The on-site manager can summarize this information in map-form or simple graphics.

Data collection and analysis program

This program is based on the initial conceptual model. The exact number and location of data collection points are somewhat flexible, being determined in the field based on actual site conditions. Levels of communications and authority between the on-site manager and the responsible party should be established to keep everyone informed as the ASC progresses.

Proper implementation of the data collection program requires that the on-site manager be familiar with the capabilities and limitations of the sampling tools and on-site analytical methods, and that he or she interpret the field-generated data as it becomes available.

The data collection and analysis program should include:

- purpose of the ASC
- initial conceptual model with site historical information, site geologic/hydrogeologic characteristics, including physical properties of the fluids and porous media
- methods to collect and analyze data
- general location and number of initial samples and the decision process for locating additional samples
- media to be analyzed
- sample collection and analysis criteria (depth interval, sampling protocol, COC, data quality levels, analytical methods and data validation)
- qualifications of the on-site managers
- site constraints (USTs, structures, canopy, limited space, utilities, property boundaries, depth to bedrock and access constraints)
- need for data collection for fate and transport modeling, risk evaluations or corrective action design
- contingencies based on reasonably anticipated deviations from expected site conditions, such as shallow bedrock, depth to groundwater, disposal of investigatory wastes, change in equipment requirements, and the appearance or detection of unanticipated COC
- determination of the possible need for off-site access

Selection of sampling tools should be based on

- purpose and anticipated scope of the ASC
- capabilities, limitations and cost of each tool
- speed by which samples can be obtained
- advantages of using a combination of tools
- site features and layout
- anticipated geologic site conditions
- anticipated COC and concentrations
- disturbance to site operations and neighboring property

Sample collection tools include the following:

- grab samplers (trowels, scoops, shovel, posthole auger)
- hand augers (slam bar and tubing)
- direct push equipment
- split spoon

- sample sleeve
- other core samplers
- active gas samplers (vacuum pumps and tubing)
- passive gas samplers
- check valve and tubing
- pneumatic depth-specific samplers
- exposed-screen sampler
- bailer
- sheathed well point
- peristaltic pump
- gas-drive/displacement pump
- gas-drive/piston pump
- bladder pump
- helical bladder pump

On-site sample analysis

Using on-site analysis, the field manager can determine the location of, or need for additional samples. **On-site analytical methods can typically provide more data at lower cost than sending samples to an off-site laboratory.** The analytical method(s) selected will depend on the following:

- the COC or indicator compounds
- the targeted medium (soil, soil vapor, groundwater, air)
- the method's ability to measure concentrations in the targeted medium

The reliability of results is related to the method's data quality level. If a specific COC such as benzene is desired, a field analytical method of a higher data quality level may be needed. Data quality considerations include these:

- a data quality level that is consistent with the purpose and scope of the ASC, and the intended data use
- often many points containing lower data quality levels can provide a better understanding of site conditions than fewer data points at a higher data quality level; thus a combination of data quality levels along with an appropriate number of data points may provide a more complete site understanding or meet regulatory requirements; for more information on data quality levels, see ASTM's Appendix X2: *An example of a data quality classification system*
- a lower data quality level is often sufficient to locate source areas or to determine the placement of monitoring wells or borings; higher data quality levels may be used to delineate concentrations of specific COC in soil or groundwater, or to locate future borings or monitoring wells

All analytical methods and instruments have limitations which can include

- temperature or humidity effects
- cross-sensitivity
- masking of certain constituents
- the operational expertise of persons handling equipment

On-site analytical methods change rapidly and may require the appropriate regulatory authority for acceptance. For instance, North Dakota and Wisconsin will not allow some on-site work for drinking water-related analyses. Each analytical method should have a standard protocol established by either a regulatory agency or industry. A quality assurance/quality control (QA/QC) plan should be developed for the methods used. A plan might include instrument calibration, review of instrument maintenance log and field logs, blank results, reproducibility, review of deviations and field standards. (The ASTM standard contains further information on instrument capabilities and time required for on-site analysis.)

The data collection and analysis program should be used to guide the site characterization to completion. **Flexibility is a key component of a successful ASC.** As workers collect and analyze data, they need to adjust the data collection and analysis program to refine the conceptual model and satisfy the purpose of the site characterization. The on-site manager interprets the data as it comes in, and from it he/she may produce maps, cross-sections and simple graphics that can help direct the investigation and fill in data gaps or resolve anomalies. New data are collected, and the investigation proceeds in an iterative, scientific manner, until the site's subsurface and nature and extent of soil and groundwater contamination are accurately defined. The degree of detail and accuracy of the graphical presentation of site conditions varies according to the purpose of the characterization, site complexity, and contaminant type and volume. Considerations for data validation include the following:

- QA/QC results
- comparison of higher data quality levels to check lower data quality levels
- consistency of results among analytical methods and sampling techniques
- comparison of results from other media
- comparison with other COC or indicator chemicals
- comparison against previous data
- data that make sense in the context of site conditions and previously generated data

The ASC is typically complete and no further data are collected when the following have been satisfied:

- the site's conceptual model, and the nature and extent of COC and indicator compounds fit the regional geologic/hydrogeologic setting
- the site's conceptual model is consistent with the site data
- the site's conceptual model can be used to make accurate predictions
- sufficient detail and delineation of the COC have been achieved to fulfill the requirements of the responsible party

In addition, constraints may prevent collection of additional data, which will terminate the data collection process.

Documentation of findings

When work is completed, a report provided by the on-site manager should contain the following:

- study approach
- statement of objectives
- background data
- description of the data collection and analysis program
- presentation or summary of the data
- QA/QC control measures

The report can help identify the following:

- no further action
- compliance monitoring
- further evaluation under the risk-based corrective action (RBCA) process
- evaluation of remedial action alternatives and subsequent selection of technologies or combination thereof

Appendices

This ASTM report also contains the following appendices:

- references (X1)
- an example of a data quality classification system (X2)
- list of physical and chemical properties and geologic/hydrogeologic characteristics (X3)
- example of the accelerated site characterization process (X4)

Reference

ASTM, "Provisional Standard Guide for Accelerated Site Characterization for Confirmed or Suspected Petroleum Releases," February 1996, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959; phone 610-832-9585, fax 610-832-9555, or e-mail: service@local.astm.org. The document sells for \$21.00.

Gilberto Alvarez, chairman of the ASTM task group, can be reached at 312-886-6143.



Field analytical methods

The following discussion is taken from the September and December 1996 drafts of the U.S. EPA manual, *Expedited Site Assessment Tools for Underground Storage Tank Sites: A Handbook for Regulators and Consultants, Chapter 6: Field Analytical Methods for Petroleum Hydrocarbons* (1996). The handbook contains much more information than that presented in this article; information for obtaining this document is given at the end of the article.

An essential element of expedited site assessments (ESAs) is field analysis. With immediate data, on-site managers can commonly establish a sampling and analytical strategy and complete a site assessment in

one mobilization. ESAs usually involve more than one type of field analytical method. The methods screen the site, identify specific chemicals of concern, identify contaminant path and migration, and/or provide a data quality check. The data quality levels (DQLs) of field analytical methods vary and their applicability may change across a site. Table 1 shows eight field analytical techniques commonly used for identifying petroleum hydrocarbons.

Detector tubes

Investigators usually use detector tubes to screen VOCs. The tubes measure volatile vapors in the air. They can also provide an indirect indication of soil and groundwater contaminant concentration. Depending on the chemical in the detector tube, individual constituents or compound groups (i.e. petroleum hydrocarbons) can be identified.

The sealed glass tubes are filled with a porous carrier material containing reagents that change color on contact with certain gases. Workers snap off the tube's breakaway ends and use a hand or electric pump to draw a known volume of air through the tube at a fixed flow rate. As contaminated air flows through the tube, the reaction of volatile compounds with the reagents produces a stain. Workers typically read contaminant concentration from a scale on the tube. For most detector tubes, stain length is proportional to contaminant concentration. In addition to

their visual observations, investigators can use an optical analyzer to measure gas-specific concentrations.

Ambient air, soil gas and liquid test kits are available. Detector tubes for hydrocarbon analyses provide readings in parts-per-million (ppm), and some can go as low as 100 parts-per-billion (ppb). The tubes can measure hundreds of compounds and compound groups including benzene, toluene, xylene, gasoline and aliphatic hydrocarbons, MTBE, O₂, CO₂ and H₂S; however, cross-reactivity can occur with compounds of similar structure. In addition, tubes have minimum and maximum operating temperatures of 32° F and 86° F to 104° F.

Fiber optic chemical sensors

Fiber optic chemical sensors (FOCS) use an optic fiber coated with a hydrophobic/organophilic chemical to detect hydrocarbons. Investigators can use FOCS for

- in-situ qualitative and semiquantitative measurements of volatile and semivolatile hydrocarbons in
 - groundwater
 - soil vapor
 - the ambient air immediately above the soil
- leak detection of liquid- and vapor-phase petroleum products
- continuous monitoring of groundwater wells, soil vapor survey wells and vapor extraction wells

Test methods	Media ¹			Analyte	Analysis time (minutes)	Cost per sample ² (\$)	Skill level	Limitations
	S	SG	W					
Detector tubes	–	✓	✓	>100 specific compounds	5 to 15	6 to 27	Low	High degree of cross reactivity
Fiber optic sensors	–	✓	✓	VOCs and SVOCs ≥ C ₆	3 to 5	1 to 10	Low	Doesn't measure specific constituents
Colorimetric test kits	✓	–	✓	Aromatic hydrocarbons	10 to 20	17 to 42	Low/Med	Colors may be difficult to distinguish
TOV methods with FID/PID	✓	✓	✓	Total VOCs	1 to 30	<1 to 10	Low/Med	Doesn't measure specific constituents
Turbidimetric test kit	✓	–	–	Mid-range hydrocarbons	15-20 (25/hr) ³	10 to 15	Low/Med	Not useful for gasoline
Immunoassay test kits	✓	–	✓	TEX/PAHs/TPH	30 to 45 (5 to 8/hr) ³	20 to 60	Med	Cross-reactivity may affect interpretation
Portable infrared detectors	✓	–	✓	TPH of hydrocarbons C ₆ to C ₂₆	5 to 20	5 to 30	Med	
Field GC	✓	✓	✓	Specific VOCs and SVOCs	10 to 60 ⁴	5 to 60	Med	Requires a skilled technician

¹ soil (S), soil gas (SG), Water (W)

² includes estimation of capital costs and disposals

³ when run in batches

⁴ longer times result when high quality sample preparations are performed

Abbreviations:

VOCs — volatile organic compounds

SVOCs — semivolatile organic compounds

TEX — toluene, ethylbenzene, xylene

PAH — polyaromatic hydrocarbons

TPH — total petroleum hydrocarbons

Table 1. Analytical methods used for identifying petroleum hydrocarbons (from OUST, 1996).

The index of refraction of the optical fiber coating of an FOCS will change depending on the hydrocarbon concentration in air or water. As hydrocarbons partition into the organophyllic coating, the change in the effective index of refraction can be determined by measuring the amount of light transmitted through the optical fiber. The response depends on the number and type of hydrocarbons present.

Fiber optic chemical sensors can detect VOCs and SVOCs with six or more carbon atoms; thus, benzene (C_6) will be detected while methane (C_1) will be missed. Readings represent a relative value; thus, investigators use a response factor (empirically determined by the manufacturer) to estimate contaminant levels once the constituents and their relative ratios have been determined. Sensor response is related to

- the quantity of hydrocarbons present in a sample, calibrated to a p-xylene response
- solubility; highly soluble constituents will yield a lower response than less soluble constituents
- temperature, with the optimal range being 10° to 30° C (50° to 86° F)

Colorimetric test kits

Colorimetric test kits can

- measure aromatic hydrocarbons in soil and water
- provide qualitative or semiquantitative screening (usually in the ppm range)
- in water analyses, detect aromatic concentrations (especially PAHs) at levels less than 1 ppm
- provide information about compound groups (e.g. BTEX)
- help determine concentrations of specific compounds

Not dependent on analyte volatility, colorimetric test kits are useful for detecting weathered gasoline, diesel and other fuel oils.

Colorimetric test kits analyze the concentration of intensely colored aromatic compounds that are formed through the Friedel-Crafts alkylation reaction. This reaction uses a catalyst, such as $AlCl_3$, to attach an alkyl group to an aromatic hydrocarbon. An alkylhalide, carbon tetrachloride (CCl_4) is typically used as a reagent and for both extraction of hydrocarbons. Once the catalyst is added, the reaction proceeds. The resulting color provides information about contaminant type; color intensity is directly proportional (within a specific range) to concentration. Color charts created from known constituent concentrations are used for comparison with measured field data.

Test kits have a number of limitations:

- an upper range of detection of 10 ppm for water, 100 ppm for soil
- relatively insensitive to fresh gasoline
- difficult to distinguish color results by visual comparison with the color charts; with low concentrations, investigators should know what constituents to expect
- false positives from interferences by chlorinated solvents
- difficult color interpretation in organic-rich or clayey soils
- difficult extraction due to clumping of clayey soils

- constituents/concentrations should be determined within 30 minutes of color formation due to their UV sensitivity
- a sample extraction solution (heptane-carbon tetrachloride) requires proper disposal if used

To allow objective measurement of color, manufacturers are developing a portable reflectance spectrophotometer.

Total organic vapor (TOV) analytical methods with flame ionization and photoionization detectors

Two TOV detectors, the flame ionization and the photoionization detectors, give an indirect indication of soil or groundwater contaminant concentration by measuring the organic constituents that partition into the headspace. The three methods used to examine the headspace are ambient air measurements, jar headspace analysis and bag headspace analysis.

Flame ionization detectors (FIDs) use a hydrogen flame to ionize organic vapors. The generated free ions can be measured as an electrical current (instrument response) which is proportional to volatile compound concentration. FIDs can detect most organic vapors; however, because they are typically calibrated with methane, an aliphatic (or chained) hydrocarbon, they are more sensitive to other aliphatic hydrocarbons.

Photoionization detectors (PIDs) use an ultraviolet lamp to ionize organic vapors. Compounds with higher ionization potentials require more energy for ionization; therefore, the strength of the UV lamp will determine the compounds that are ionized. UV lamps range in energy from 9.5 to 11.7 eV. The higher energy lamps ionize a broader range of hydrocarbons. PIDs are most sensitive to other aromatic (or ringed) hydrocarbons such as BTEX compounds. As with FIDs, the instrument response is proportional to the electric current generated by the ionized compounds. Isobutylene is typically used as the calibration gas for PIDs.

Table 2 contrasts some FID and PID characteristics.

Turbidimetric test kits

Investigators use turbidimetric test kits—a screening device—for measuring total petroleum hydrocarbon (TPH) content in soil. The kits

- provide quantitative screening of soil for the presence of midrange petroleum hydrocarbons (diesel, fuel oils, grease or C_{12} to C_{30} hydrocarbons)
- can be used to identify contaminants in the vadose zone
- are being adapted for analysis of TPH in water

The kits indirectly measure TPH in soil by suspending extracted hydrocarbons in solution and then measuring the resulting turbidity (relative cloudiness) with a turbidimeter. The suspending solution causes extracted TPH to precipitate while remaining suspended. The concentration of petroleum hydrocarbons in the soil is directly proportional to the turbidity measurement; thus, kit manufacturers can develop a standard calibration curve to estimate TPH concentration.

	FIDs	PIDs
Compounds detected	Aliphatic and aromatic hydrocarbons	Aromatics and some aliphatics
Linear range of detection	1 to > 1,000 ppm Some up to 10,000 ppm	1 to < 300 ppm
Unfavorable environmental conditions	High CO ₂ , low O ₂ (<15%), high winds, temperature below 32° F	High humidity (90%), > 1 % CH ₄ , low O ₂ (<15%) temperature < 32° F
Other issues	Requires a hydrogen source Requires more training than PID High methane levels (produced by natural gas) may be interpreted as contamination	Adversely affected by electrical power lines and transformers Methane can depress readings
Common to both	Affected by low air flow Poor detection of weathered gasoline	

Table 2. Comparison of FIDs and PIDs (adapted from OUST, 1996).

The test consists of three parts:

- hydrocarbon extraction from the soil using a solvent
- separation of extract with a filter and developing solution
- analysis of the solution with a turbidity meter; turbidity value is proportional to the amount of petroleum hydrocarbons present

Other issues concerning the test should be recognized:

- constituents should be identified before using the test so a response factor can be selected from a reference table
- light-weight petroleum hydrocarbons (such as gasoline) are not detected
- filtration can be difficult with clay soils
- the meter can be calibrated using an extraction solvent vial as a blank
- the calibration standard is provided with the kit
- samples can be run individually or batched
- optimum performance and throughput are recommended by running groups of 10 samples along with a blank and a standard
- results are given in the ppm range
- organic-rich soils may limit effectiveness of the extraction or cause a positive interference
- high moisture content in the soil may dilute hydrocarbon concentration in the extract, resulting in negative interference
- time for analysis is 15 to 20 minutes; 25 samples per hour analyzed when batched

Immunoassay test kits

Investigators use these kits to measure petroleum hydrocarbons in soil and water. They can measure groups of compounds (such as short chain hydrocarbons) or a general assay range (such as PAH or TPH). The kits can be used for screening, semiquantitative screening or for quantitative analyses.

The kits use antibodies (proteins developed by living organisms to identify foreign objects) to identify and measure target constituents (antigens) through an antibody-antigen reaction. Antibodies can identify specific compounds because they have binding sites designed to preferentially bond to specific antigens. To facilitate analysis, immunoassay test kits use reagents (enzyme conjugates) that allow for color development. For most immunoassay test kits, the color is inversely proportional to the contaminant concentration. A more exact contaminant concentration can be determined by comparing the color developed in the sample with a reference standard. The comparison can be made visually, with a portable photometer, or with an optical reflectance meter. The OUST (1996) manual gives details on how to perform the water and soil tests.

Other test issues for investigators include these:

- kits are designed to test for specific analytes or a range of analytes and are not capable of measuring a category as broad as all petroleum hydrocarbons; thus tests do not measure every constituent present in fuel
- cross-reactivity can occur, resulting in false positives; however, this data is available from the manufacturer
- "BTEX" test kits measure short chain hydrocarbons but can give results that correspond with TEX concentrations for gasoline constituents; these tests have a low selectivity for benzene
- tests must be run within specified temperature ranges (usually 40° to 90° F)
- clay and organic-rich soil can limit soil extraction effectiveness
- field extraction of PAHs may be less effective than laboratory extraction methods
- a new strip test being developed will simplify the analytical method and interpretation
- kits can be damaged if frozen or exposed to prolonged heat

Portable infrared detectors

Portable infrared (IR) detectors measure the total petroleum hydrocarbons (TPH) in soil and water samples. The instruments are really spectrophotometers: they measure IR radiation absorbance of sample extracts. The hydrogen-carbon bond of petroleum hydrocarbons will absorb IR radiation at specific wave lengths, and these absorption measurements can be directly related to TPH concentrations by using calibration standards. The method requires development of standards so that sample measurements can be correlated to actual concentrations. Issues of concern include:

- the method can measure TPH of the C₆ to C₂₆ range
- results are biased toward hydrocarbons greater than C₁₂ because of their larger response to IR; thus IR detectors are not effective for measuring VOCs
- responses are biased toward aliphatic hydrocarbons due to their larger response to certain IR wave lengths
- method detection limits are 2 ppm for soil and 0.08 ppm for water
- operational temperatures are between 40° F and 104° F
- results cannot be correlated with health or environmental risks because all hydrocarbons are grouped together and represented as one number
- compounds of interest must be extracted; extraction efficiency is much lower in clays than sands
- terpenes, found in conifers, citrus oils and eucalyptus, are not removed and can cause false positives

Field gas chromatographs

Field gas chromatographs (GCs) provide the highest data quality of all the commonly used field analytical methods. They measure individual constituents. Field GCs have two major parts: a column that separates individual constituents and a detector that measures constituent quantity. The detectors used for hydrocarbon analysis are PIDs or FIDs.

Field GCs can be portable (durable, compact and light enough to carry) or transportable (usually mounted in a mobile laboratory). The transportable GCs are capable of providing better constituent separation and thus more accurate identification and quantitation. Issues of concern regarding field GCs:

- they can give soil, soil-gas and water analyses
- soil gas analyses are the simplest to analyze since they require no preparation
- water samples must be tested with a static headspace or purge-and-trap methods
- soil samples are tested with static headspace or solvent extraction methods
- GCs can test for volatile and semi-volatile hydrocarbons
- GCs do not measure a wide range of hydrocarbons
- analytical schemes usually don't measure low volatility and nonvolatile hydrocarbons (such as crude oil)
- GCs can measure constituent concentrations in ppm and sometimes as low as ppb

- field GCs are the only field method for accurately determining MTBE concentrations
- GCs must be used in areas where variations in temperature are minimized and ambient air is not contaminated
- highly contaminated samples may require dilution
- nontarget constituents may interfere with peak resolution if they have similar retention times or coelute with the target compounds
- many interfering peaks can obliterate identification
- high degree of operator training is required

Emerging methods

Several new field analytical methods—emerging methods because they are not yet widely available—include:

- gas chromatography/mass spectrometry (portable and transportable)
- in-situ analysis using direct push technologies: laser-induced fluorescence, fuel fluorescence detector and a semi-permeable membrane sensor with a PID or FID

Reference

OUST draft of *Expedited Site Assessment Tools for Underground Storage Tank Sites: A Handbook for Regulators and Consultants, Chapter 6, Field Analytical Methods for Petroleum Hydrocarbons*, 1996, Washington D.C.; final manual available from: Government Printing Office, 202-512-1800.

UTTU thanks Robert Hitzig, OUST, for his help on this article.



Direct push technologies

Direct push technologies are invasive approaches that involve pushing or driving probes into the subsurface. Investigators use the techniques to characterize shallow subsurface conditions, including petroleum-contaminated sites (*Daniels and Grumman, 1995*). The development and use of these innovative technologies has grown tremendously in the last decade. (*According to one editor, some of the information in the Daniels and Grumman document cited above may already be obsolete.*) Until the mid-1980s, environmental professionals used site characterization technologies borrowed from geotechnical, water well drilling and other industries to characterize sites. "When the costs of conventional investigations and long-term groundwater monitoring were totaled, it became clear that the environmental industry needed better ways to characterize contaminated sites more quickly and more thoroughly" (*Einarson, 1995*).

Direct push technologies include the following:

- hydraulic soil probing (HSP) with small-diameter probes for soil gas, soil and water sampling; the probes can be single rod or cased systems
- cone penetrometer testing (CPT) to define the stratigraphy of unconsolidated sediments

*Note: OUST's new manual (see previous article) **Expedited Site Assessment Tools for Underground Storage Tank Sites: A Handbook for Regulators and Consultants**, has an excellent chapter on direct push technologies: they also use a different classification for DP tools.*

Direct push vs. conventional drilling

A drawback of the direct push (DP) tools used to be their inability to successfully and quickly collect continuous soil cores; however, some direct push tools such as Enviro-core^R can compete with conventional drilling and augering in this respect. Continuous soil cores are used to identify thin permeable layers, artificial fill, zones of discolored soil, free product and features such as root holes or desiccation cracks. These features often control contaminant movement. On the average, conventional drilling as opposed to direct push technologies

- can go deeper
- can drill through more types of materials and is less affected by obstructions

According to Daniels and Grumman (1995), "Augering and many traditional drilling procedures have been widely accepted, and in some cases, even codified by regulatory agencies." Thus regulatory requirements "may limit the utility of HSP and CPT groundwater monitoring installations, unless changes in the regulations are enacted. Since [regulations pertaining to] well standards are so pervasive, it may be difficult to introduce different monitoring well codes without a corresponding loss of industry-wide standardization."

DP tools have these advantages over conventional drilling:

- speed and cost
- on-site field capabilities
- minimal surface disturbance

Daniels and Grumman (1995), however, caution that neither CPT or HSP are a "complete substitute for conventional drilling and sampling methods. . . . and the methods . . . deserve further research and development to more fully assess their potential for detecting and mapping hydrocarbons." A description of three innovations in DP technologies follows.

HSP — Hydraulic soil probing uses a probe that is typically 1 inch (2.5 cm) to 1.5 inches (3.8 cm) in diameter. Workers (usually a two-person crew) drive the probe into the ground with percussion hammers. The probes sample soil gas, soil cores or groundwater (Christy and others, 1994). Recent improvements in tools and driving mechanisms have increased investigation depth to 100 feet (30 m), although this will depend on site-specific geologic conditions. The technique is principally intended to retrieve "undisturbed" soil samples, soil vapor and groundwater from the 10- to 30-foot (3 to 10 m) depth (Daniels and Grumman, 1995).

The tool is "a kind of hybrid between a conventional auger drilling and cone penetrometer testing. . . . HSP operates by pushing a cone-tipped drill stem into the subsurface. The downward force on the drill rods is applied using a hydraulic

pressure system and percussive force coupled with the static force of the HSP vehicle itself—no rotation of the drill rods is required. The percussive force is similar to that of a construction 'jack-hammer.' The drilling system is relatively compact and easily fits into the back of a cargo van" (Daniels and Grumman, 1995).

To sample soil, workers advance the drill rods to a depth just above the sampling depth. "The drill stem is removed from the hole and a sealed sampling probe is lowered into the borehole. The sampling probe is positioned at the bottom of the hole and a core sample is obtained by pushing the opened sampling probe the required sample distance. The sampling probe is a hollow cylinder, with a detachable hardened-steel tip, and may contain a plastic liner (sleeve) that permits easy extraction, observation and preservation of the sample core" (Daniels and Grumman, 1995).

A variety of configurations of borehole logging tools can be part of the HSP system. These tools vary with

- diameter
- contact spacing
- number of contacts employed
- configuration of the current/voltage array

The HSP system has several advantages:

- conductivity logs can be made through small-diameter holes using light, mobile probing units
- multiple logs can be run in a single day
- speed; for instance, five to eight 6 m (20 ft) holes can be drilled during an 8-hour day
- the technique does not require the pre-drilling of a borehole for the logging operation (this also eliminates cuttings generated)
- simple decontamination of equipment
- easy access to many sites
- soils that are collected in plastic liners
- accessory sampling equipment available
- on-site lab testing possible
- considerably safer and simpler operation than conventional drilling

Recently Christy and others (1994) developed a probe for the measurements of soil conductivity with depth. (Soil conductivity can help investigators distinguish sands from shales.) "The primary hurdles in the development of this tool concern the aggressive vibrations that a driven tool is subjected to. Prototype models of this probe experienced failures from vibration in contact rings, electrical conductors and isolating materials. Each of these failure areas was analyzed and changes were made in the design and construction of the probe and materials to extend probe life" (Christy and others, 1994).

Because the probe is subjected to high shock from the hydraulic hammer, the electronics are not built into the probe; instead, the electronics and all signal conditioning circuitry for voltage and current measurement are housed in a separate rugged case. This construction strategy also makes the probe less expensive to replace in case of failure in the field (Christy and others, 1994).

A recent technical improvement is a driveable permeable membrane sensor for detecting volatile contaminants as the probe is driven into the soil. The sensor allows volatile compounds in the soil to diffuse across a permeable membrane while the investigator obtains a continuous log of sensor response to the contaminant with depth. The sensor relies on diffusion rather than bulk flow of liquid or gas and thus can operate in the vadose and saturated zones. This rugged sensor can be driven into the ground using percussion-type direct push techniques (*Christy, 1994*).

HSP systems have a number of disadvantages:

- they are operable only in unconsolidated formations
- sample volumes obtained can be small
- because the technique is so new, few standards exist for defining the method
- deep drilling can be slow and difficult
- surface obstructions or very dense soils can prevent penetration
- when drilling through unconsolidated materials, the materials can "slough" or cave in between samples and ruin the hole unless the HSP hole is cased
- the narrow diameter of the drill holes does not permit installation of the conventional 2-inch diameter monitoring wells

CPT — Cone penetrometer testing is also a direct push technology. Workers push a small-diameter (1.4 to 2 inches outside diameter), instrumented, cone-tipped probe (penetrometer) into the ground while a computer data acquisition system analyzes the soil response to penetration along its probe tip and sides; an instrumented probe head obtains continuous logs of the subsurface's mechanical and electrical properties. The tool uses resistivity measuring techniques used in borehole logging tools, but it has the added advantage of direct contact between the soil and the probe without the need for conventional drilling. CPT, however, is not well suited for direct soil sampling, although at shallow depths, soil sampling is relatively easy (*Daniels and Grumman, 1995*).

The tool works in the following way: "The penetrometer is mounted at the bottom of a string of hollow steel rods. A hydraulic ram is used to push the hardened-steel cone-tipped penetrometer into the ground at a constant rate of approximately 1.2 m/minute (4 ft/minute). Electronic signals from downhole sensors are transmitted by a cable strung through the sounding rods, to a computer data acquisition and display system. Multi-channel measurements are monitored in real time and simultaneously recorded digitally. No borehole is required during penetrometer operations: penetrometers are directly thrust into the soil from the ground surface" (*Daniels and Grumman, 1995*).

ASTM D-3341-86 (1986) is the standard procedure for describing applications of CPT. The CPT measures soil resistance to penetration along the probe tip and sides, and it can also be equipped with the following:

- a pressure transducer to acquire hydrologic information such as piezometric data

- a soil electrical conductivity sensor to acquire hydrogeological and qualitative geochemical data

Use of the CPT presents several advantages:

- probing is fast (up to 1.2 m/minute)
- logging is continuous
- productivity can range from 100 to several hundred feet per day, depending on the geologic site conditions
- deeper probing than HSP and small drill rigs—reaching depths of 60 m (200 ft) under good conditions
- multiple logs per hole can be run
- consistent, automated interpretation of stratigraphy
- generation of minimal soil cuttings
- testing of in-situ hydraulic permeability

According to Daniels and Grumman (1995), the CPT can "differentiate subtle differences in physical properties that may permit CPT to identify zones of contamination. In particular, it has been hypothesized that an anomalously low electric log response may be observed within a zone saturated by poorly conducting petroleum contamination. While some studies have suggested that this effect can be observed in granular formations, especially where a measurable thickness of floating product is present, further research may be required to establish a more reliable basis for interpreting these data."

Limitations of CPT include the following:

- the large vehicle size and heavy weight (10 to 20 tons) can restrict site access
- obstructions can force the termination of CPT
- direct soil sampling can be time-consuming
- determinations are inferential and non-direct
- groundwater sampling can be time-consuming in low-permeability formations
- difficult or impossible to penetrate consolidated formations
- unlike a drilling rig, the CPT rig can, with little or no warning, easily penetrate objects such as USTs or utilities

Enviro-Core^R — In 1990 a company in California miniaturized the drive casing and wireline core barrels used in conventional drilling rigs. They developed a method to quickly advance the small-diameter sampling tools into unconsolidated sediments without rotating the drill string. This Enviro-Core^R system cases the borehole as it deepens and rapidly collects continuous cores, soil gas samples and groundwater samples. Like other direct push systems, no drill cuttings are generated; unlike other direct push systems, the Enviro-Core^R is not blind because samples can be retrieved. As the core is advanced, less soil compaction occurs than with other direct push systems since most of the soil is collected inside the inner barrel and later removed from the boring. Thus, creation of a low-permeability compacted zone is minimized, facilitating a more rapid collection of soil gas and groundwater samples (*Einarson, 1995*).

This system uses small, portable vibratory rigs, although it can use CPT and conventional drilling rigs to advance the probe. The system can sample to depths of 50 feet with nearly 100 percent recovery and can collect up to 150 feet of continuous cores per day.

According to Einarson, "This sampling system consists of small-diameter casing and an inner sample barrel that are simultaneously pushed, pounded or vibrated into the ground. Continuous soil cores are collected in stainless steel liners inside the inner barrel. After being advanced three feet, the inner barrel is retrieved while the drive casing is left in place to prevent the borehole from collapsing. The drive casing ensures that subsequent soil samples are collected from the targeted interval, rather than potentially contaminated slough from higher up in the borehole."

"The use of small-diameter drive casing facilitates in-situ hydraulic testing, geophysical logging and installation of small-diameter piezometers, monitoring points, air sparging points, and SVE points. The Enviro-Core^R drive casing may also provide a way to selectively fracture contaminated, fine-grained strata in order to improve the effectiveness of many in situ remediation techniques" (Einarson, 1995). In addition, the system provides an open, cased boring in which geophysical logs (natural gamma, neutron, and gamma-gamma) can be run in the borehole.

References

Christy, T.M., "A Driveable Permeable Membrane Sensor for the Detection of Volatile Compounds in Soil," 1994, Geoprobe Systems, 601 N. Broadway, Salina, Kansas 67401; 800-436-7762.

Christy, C.D., Christy, T.M. and V. Wittig, "A Percussion Probing Tool for the Direct Sensing of Soil Conductivity," 1994, Technical Paper No. 94-100; Geoprobe Systems, 601 N. Broadway, Salina, Kansas 67401; 800-436-7762.

Daniels, J.J. and D.L. Grumman, "Report on Leaking Underground Storage Site Exploration Technology Assessment: Field Demonstration Project," February 3, 1995, U.S. EPA Region V, project number L-995395-01-0.

Einarson, M.D., "Enviro-Core^R—a New Direct-Push Technology for Collecting Continuous Soil Cores," paper presented at the 9th Annual National Outdoor Action Conference, Las Vegas, Nevada, May 1995; 614-337-1949

The February 1993 issue of *UTTU*, Vol. 7, No. 3, has the following CPT articles:

- Cone penetrometer sampling
- Cone penetrometer use in southern Ohio
- Cone penetrometer and sampling probe references

Additional *UTTU* references on field techniques

- Fiber optics and cone penetrometers, Vol. 10, No. 1, 1996
- Analysis of basic field screening techniques, Vol. 9, No. 3, 1995
- Integrated field techniques, Vol. 9, No. 1, 1995

From *UTTU* Vol. 8, No. 2, 1994:

- Analytical field techniques
- The field gas chromatograph
- Operational concerns of total organic vapor detection instruments
- Field and laboratory data comparison
- Working with an analytical laboratory
- Field and laboratory terms
- References on field analytical techniques

• Immunoassay testing, Vol. 7, No. 2, 1993

From *UTTU* Vol. 7, No. 5, 1993:

- How valid are soil VOC measurements?
- Difficulties quantifying VOCs in soil samples
- Evaluating soil-sample VOC holding times
- Screening soils for VOCs using the headspace method
- ASTM recommendations for handling/sampling soil VOCs
- References on sampling and handling soil VOCs

- Ground-penetrating radar, Vol. 7, No. 4, 1993
- Summary of geophysical methods, Vol. 7, No. 4, 1993
- Lab in a bag, Vol. 6, No. 1, 1992

From *UTTU* Vol. 5, No. 4, 1991:

- Surface geophysical investigation techniques
- Geophysical borehole techniques
- Using electrical resistivity to identify transmissive zones
- Geophysical references

- Monitoring well construction, Vol. 5, No. 2, 1991
- Limitations of groundwater monitoring wells, Vol. 5, No. 2
- Portable gas chromatographs, Vol. 5, No. 1, 1991
- Soil gas surveying, Vol. 4, No. 4, 1990

From *UTTU* Vol. 4, No. 3, 1990:

- The fiber optic chemical sensor
- Screening groundwater samples with a portable gas chromatograph



The Fury robotic system

Federal regulation 40 CFR 280-281 requires a credible inspection of fuel-holding tanks 10 years old or more by December 1998. Depending on condition and age, the tanks can be retrofitted with a liner and/or cathodic protection (CP), replaced, or taken out of service. Some owners are pulling tanks without inspecting them, but with more than a year to comply, owners might want to explore other options before embarking on an expensive replacement program.

A new robotic system, Fury, can inspect underground storage tanks (USTs) without emptying the tank or cutting a manway for access. If a valid inspection shows a tank is not leaking, the tank owner/operator can add CP at a fraction of the cost to install a new tank. It is estimated that 70 percent

of the 800,000+ petroleum, oil and lubricant (POL) tanks do not have leaks and could meet the standards by retrofitting with a CP system. There are about 20,000 USTs on Army installations alone.

CERL (U.S. Army Construction Engineering Research Laboratories) and Redzone Robotics developed the Fury robotic system. The robot can enter a tank through existing risers that are as small as four inches in diameter. Inside the tank, the robot moves over both end caps and the wall area on magnetically coupled wheels. Fury uses an ultrasonic transducer to take multiple measurements of the tank wall thickness throughout the tank.

In contrast, manual inspection techniques involve emptying the tank, cutting a hole large enough to permit human entry, and cleaning the inside so that the work environment meets all requirements of the Occupational Safety and Health Administration (OSHA). Most inspectors use the "hammer test", by which the sound of a hammer tap is associated with a tank wall's thickness. The American Society for Testing and Materials standard ES 40-94 (which expired on November 15, 1996) describes both invasive and noninvasive alternatives to this approach.

The Fury system will cost \$50,000 to \$100,000. Service providers will offer inspections at about \$1,200 per tank. In comparison, manual inspection costs are \$1,400-1,800 per tank; defueled tanks cost \$2,800 to \$3,600 each for manual inspection. At Army sites, inspectors must be fully insured to do this type of inspection. In addition, if sludge has built up on the tank bottom, it has to be treated as a hazardous waste.

Commercial availability of the Fury system is expected in early 1997. For more information, contact Dr. Charles Marsh or Vincent Hock at CERL, 217-373-6764 or -6753.



The view from U.S. EPA: expedited site assessment

The U.S. EPA Office of Underground Storage Tanks (OUST) encourages the use of expedited site assessments (ESAs) to streamline the corrective action process, improve data collection and reduce remediation costs. OUST believes that using ESAs is especially important for the immediate future. Of the 1.1 million federally regulated USTs, OUST estimates that 500,000 USTs currently meet the December 22, 1998 regulatory deadline, which requires USTs to be upgraded, replaced or closed. OUST anticipates about 300,000 closures and 100,000 confirmed releases over the next three years. Although many of these confirmed releases will be discovered at closure, all sites will require an assessment. In addition, of the 315,000 releases already confirmed, about 64,000 of these need to initiate cleanup activities. As a result, more than 350,000 sites are likely to require site assessments in the next few years.

The ESA process

The ESA process is a framework for rapidly characterizing UST site conditions. ESA is also known as accelerated site characterization, rapid site characterization or expedited site investigation. An ESA typically involves a single mobilization and can cover several days. Features of an ESA include

- field-generated data and on-site interpretation
- a flexible sampling and analytical program
- senior staff authorized to make sampling and analytical decisions in the field

In contrast, most data analysis and interpretation of a conventional site assessment (CSA) are completed off-site, and at a later date. Thus, CSAs usually

- take weeks or months to generate a preliminary report
- require several phases of investigation
- delay corrective action decisions for months or years

ESAs have been made possible recently by the development of improved, cost-effective methods for rapid collection and field analysis of soil, soil-gas, and groundwater samples. When appropriate, conventional sampling and analytical methods can be incorporated; for example, off-site certified laboratory analysis may be used to verify field analytical methods. The ESA process emphasizes the appropriate use of technologies to minimize the time required for complete site characterization and maximize the data available for making corrective action decisions.

CSAs usually focus on installing groundwater monitoring wells with limited subsurface information. The sampling and analysis plan is typically rigid. Workers perform most data analysis off-site, and results may take weeks or months to produce. Results are usually focused on mapping the groundwater plume boundaries rather than the source areas, or locating the most significant contaminant mass. This approach generally ignores the 3-dimensional nature of contaminant migration. Consequently, the CSA process tends to be time-consuming and costly, and the site characterization is often incomplete or incorrect.

In contrast, the ESA process uses senior scientists as field managers to conduct the entire assessment. Both types of assessments evaluate existing data to develop an initial conceptual model of site conditions; however, the ESA's sampling and analysis plan is dynamic: newly generated site information directs the assessment and helps update and refine the conceptual model. Thus data gaps are filled and anomalies are resolved prior to demobilization. The ESA is complete when the data obtained agree with the 3-dimensional site model.

ESAs and RBCA

Risk-based corrective action (RBCA) is a detailed framework that uses risk and exposure assessment methodologies to help UST-implementing agencies determine the extent and urgency of corrective action. The American Society for Testing and Materials (ASTM) RBCA standard uses a three-tiered approach—with each tier requiring more

site-specific data—to evaluate sites and establish state risk-based policies.

The information from ESAs can be integrated with RBCA evaluations. The first two RBCA tiers can be evaluated in a single mobilization as part of a standard ESA, provided the investigator has the cooperation of the appropriate regulatory agency. The data needs for a tier 3 evaluation can also be acquired in the same mobilization; however, because of the required data complexity and cost, investigators should prepare for this tier level prior to mobilization. In addition it may be necessary to acquire, in advance, authorization from the implementing agency before collecting the tier 3 data.

To encourage the use of ESAs, OUST has produced *Expedited Site Assessment Tools for Underground Storage Tank Sites: A Guide for Regulators* (EPA 510-B-97-001). The final document is likely to be ready by March 1997. The manual, which can be ordered from the Government Printing Office (202-512-1800), contains detailed information on the expedited site assessment process, surface geophysical methods, soil-gas surveys, direct push technologies, and field methods for petroleum hydrocarbon analysis.



Information sources

Publications

The U.S. EPA's *Closing Underground Storage Tanks: Brief Facts* (EPA-510-B-96-004) is available on EPA's CLU-IN as files WISCON.1, WISCON.2 and WISCON.3 in Directory 11. Call Hal White at 703-603-7177 for help accessing CLU-IN or access OUST's home page: <http://www.epa.gov/OUST>.

Publications from CERL (513-569-7562) include:

- *Nonaqueous Phase Liquids Compatibility with Materials Used in Well Construction, Sampling and Remediation* (EPA/540/S-95/503)
- *Light Nonaqueous Phase Liquids* (EPA/540/S-95/500)
- *Low-Flow (Minimal Drawdown) Groundwater Sampling Procedures* (EPA/540/S-95/504)
- *Manual: Groundwater and Leachate Treatment Systems* (EPA/625/R-94/005)

Publications from NTIS (703-487-4650) include:

- *Surfactant Injection for Groundwater Remediation: State Regulators' Perspectives & Experiences* (EPA/542-R-95-011)
- *State Policies Concerning the Use of Injectants for In-Situ Groundwater Remediation* (EPA-542-R-96-001)

From Ann Arbor Press (313-475-8787 or 800-858-5299):

- *EPA Environmental Assessment Sourcebook* and *EPA Environmental Engineering Sourcebook* (\$59.95 ea.)
- *Groundwater Contamination from Stormwater Infiltration* (\$49.95)

The *Market for Bioremediation Products and Services* is available for \$2,250 from FIND/SVP, Department RG, 625 Avenue of the Americas, New York, NY 10011-2002.

In-Situ Treatment Technology, Lewis Publishers/CRC Press, from Geraghty & Miller (\$69.95); 800-425-6127 or 303-294-1200.

A guidance resource for the natural restoration of sites contaminated with chlorinated solvents is available at the Web site: <http://www.rtdf.org>

For a free copy of *Anaerobe*, call 800-894-3434 or contact the editor by e-mail: copies@apuk.co.uk

Web sites

Web pages from Battelle include:

- Environmental division: <http://www.estd.battelle.org/>
- Atmospheric processes to waste solidification/stabilization: <http://www.estd.battelle.org/services/.html/>
- Systems analysis and engineering: <http://battelle.org/sae/sae.html/>
- Books from Battelle: <http://www.battelle.org/bp/bptotc.html/>

Subscriptions and address corrections

Any person or organization wanting a subscription to *Underground Tank Technology Update (UTTU)* should send requests and subscription fee (free to state government employees) to

Debbie Benell
432 North Lake St.
Madison, WI 53706
tel. 608/263-7428

Subscriptions begin with the first issue of each year; those who subscribe during the year will receive all issues in the volume.

Please send address corrections to the above address. Back issues (bimonthly from April 1987) are available. Please check the form.

☐ YES, put me on your *UTTU* mailing list.

___ I'm enclosing the \$25 (1-yr) subscription fee.

___ Free. See my state government employer below.

☐ YES, send me *UTTU*'s previous issues.

___ I am enclosing \$30.

___ Back issues free. See state government employer below.

NAME _____

TITLE _____ PHONE _____

COMPANY/ STATE GOV. EMPLOYER _____

ADDRESS _____

CITY _____ STATE _____ ZIP _____

Make checks payable to University of Wisconsin-Madison

OUST's home page: <http://www.epa.gov/OUST/> or <http://www.epa.gov/epaoswer>

CLU-IN electronic bulletin board system: <http://clu-in.com>
CLU-IN contains information on remediation technologies, site characterization, partnerships and consortia, regulations, publications and software, and internet and online resources.

Other sites

American Geophysical Union:

<http://earth.agu.org/kosmos/homepage.html>

BCSS Statistical Software:

<http://amsquare.com.ncss/>

Business & Legal Reports:

<http://www.safetyonline.net/blr/>

Environmental Organization Web Directory:

<http://www.webdirectory.com/>

Minnesota District Home Page:

<http://www.mn.cr.usgs.gov/index.html>

National Atmospheric Deposition Program/National Trends Network: <http://nadp.nrel.colostate.edu/nadp/>

National Groundwater Association:

<http://www.h2o-ngwa.org/>

National Water Quality Laboratory Home Page:

<http://www.nwql.cr.usgs.gov/>

Nature: <http://www.nature.com/>

On-Line Resources for Groundwater Studies:

<http://gwrp.cciw.ca/internet/online.html>

Selected Water Resources Abstracts:

<http://h2o.usgs.gov/public/nawdex/swra.html>

Soil and Groundwater Cleanup: <http://www.gvi.net/soils/>

Soil and Water Conservation Society:

<http://www.netins.net/showcase/swcs/>

The Soft Earth: http://wombat.es.mq.edu.au/Oc:/s_earth.html

The Virtual Earth: http://wombat.es.mq.edu.au/Oc:/v_earth.html

U.S. Water News: <http://www.mother.com/uswaternews/>

United States Geological Survey Home Page:

<http://www.usgs.gov/>

Readers are invited to send web site addresses to Pat Komor (pdkomor@msn.com) and suitable site addresses will be published in a future issue of UTTU.

Phone numbers

EPA hotline: 800-424-9346. For questions concerning the December 22, 1998 deadline on tanks installed before December 22, 1998, call this number.

The American Chemical Society Hotline: 404-365-2447.

Conferences and training

The Seventh Annual West Coast Conference on Contaminated Soil and Groundwater will be held in Oxnard, California. Call Jennifer Howland at 413-549-5170 or fax 413-549-0579.

In-Situ and On-Site Bioremediation: the Fourth International Symposium, will be held April 28 to May 1, 1997 in New Orleans, Louisiana. Call 800-783-6338 or fax 614-424-3819 or get more information by internet at sheldric@battelle.org.

The First International Conference on Remediation of Chlorinated and Recalcitrant Compounds will be held May 18-21, 1998 in Monterey, California. For information, call Battelle at 800-783-6338 or 614-424-5461, or fax 614-488-5747, or internet 102632.3100@compuserve.com.

The Nielsen Environmental Field School offers courses in environmental site characterization and field hydrogeology. Contact David Nielsen, Nielsen Environmental Field School, 4684 State Route 605, South Galena, Ohio 43021-9652 or phone 614-965-5026 or fax 614-965-5027.

For information on the *Sixth Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst*, April 6-9, 1997 in Springfield, Missouri, call Dr. Barry F. Beck, LaMoreaux & Associates Inc., P.O. Box 4578, Oak Ridge, Tennessee 38731-4578 or call 423-483-7483.

International Business Communications conferences:

- *Brownfields Redevelopment* (April 10-11)
- *Phytoremediation* (June)

Ph: 508-481-6400; fax: 508-481-7911 or e-mail: reg@ibsucs.com

Research and new techniques

To learn more about a methodology for using soil-gas data to evaluate the threat of vadose-zone VOC contamination to groundwater, contact Keerfoot & Associates, 2200 E. Patrick La., Ste. 23, Las Vegas, Nevada 89119, phone 702-891-0100 or fax 702-891-0426.



Underground Tank Technology Update

The College of Engineering
University of Wisconsin-Madison

Engineering Professional Development
432 North Lake Street
Madison, Wisconsin 53706

Nonprofit
Organization
U.S. Postage
PAID
Madison, WI
Permit No. 658